The cognitive basis for restrictions on vowel harmony

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Goal of This Talk:

Learning Involves:

- Abstract Phonological Representations
  - Features
- Constrained by universal grammatical principles
  - Reflected in typological frequency

- Artificial grammar learning experiments can tap into adult phonological representations

Traditional View of Features

- Abstract Learning: Features
- Abstract features traditionally assumed in theoretical phonology
  - SPE feature bundles
  - Autosegmental tree structures, etc.
  - Vowel harmony in SPE

$$V \Rightarrow [\alpha\text{Back}] \;/\; \underset{[\alpha\text{Back}]}{V} \quad \underline{\qquad}$$

Challenges to Abstract Features

- Exemplar-models (Johnson 2006; Port & Leary 2006, etc)
- No need for abstract features
- Store
  - lexical items
  - fine-grained phonetic details
  - statistics
- Compute similarity
- Vowel harmony in exemplar models: statistics over co-occurrence
  - agreeing front vowels, high percentage [i e], [e i]
  - agreeing back, high percentage [u o] [o u], etc.
  - disagreeing vowels, low percentage, * [i u]

Finding Evidence for Features

- Artificial Grammar Learning: Poverty of the Stimulus (Wilson 2006)
  - Test generalization to novel segments/structures
  - Not testing for nativism
- Train Participants on Novel Mini language
    - Brief auditory exposure to language
    - Limited exposure to inventory of possible segments to undergo rule
- Test
    - Old Items (identical to training)
    - New Items (novel words, same segments as training)
    - New Segments (include 'hold-out' vowels)
      - generalization to novel segments = feature-based learning

Poverty of the Stimulus and Vowel Harmony (Wilson 2006)

- Vowel Harmony:
  - Process whereby vowels agree for some feature [Back], [Round], etc.
  - Induces morphophonological alternations
    - nek/nak (Hungarian)
  - Not in English (use monolingual English-speaking participants)
  - Learnable process (Pycha et al 2003, Wilson 2003 (nasal assimilation))

Poverty of the Stimulus and Vowel Harmony (Wilson 2006)

-Artificial Back Harmony:
- 6 vowel inventory
- Training Includes 4 vowels
- Test Includes all 6 vowels

Front	Back	
i	u	Training/Test
e	**o**	**TEST ONLY**
æ	a	Training/Test

Experiment 1: Back Harmony

- Will adult learners of an artificial back harmony language generalize to novel segments?
- Is there a difference in generalization based on vowel height?

Experiment 1: Back Harmony

- Stems trigger alternation in suffix vowel
  - Stems: CVCV
    - consonants [p, t, k, b, d, g, m, n]
    - 6 Vowels Total:
      - front [i, e, æ]
      - back [u, o, a]
  - Suffix alternates between
    [-mi] (front)/ [-mu] (back)
- Front vowels trigger [-mi]
  - [bige] ⇒ [bigemi]
- Back vowels trigger [-mu]
  - [bugo] ⇒ [bugomu]

Experiment 1: Stimuli

- Naturally produced stimuli
  - Adult male
    - Native English Speaker
  - English Vowels
- Intensity Scaled to 70 db
- Stimuli rated by 1st author and 2 native English speakers

Experiment 1: Hold-Out Conditions

- 4 Vowels in training
- 2 Hold-Out Conditions
- Low Hold-Out: [i, e, u, o]
- Mid Hold-Out: [i, u, æ, a]

4 Learning Hypotheses

- Segment-Based Learning: Learners learn rule based on individual segments
  - no generalization to novel segments
- Formally Restricted Feature-Based Learning: Abstract learning but to the smallest possible natural class
  - generalization to mid but not low vowels
- General Feature-Based Learning: Learners learn a general, abstract rule
  - generalization to mid and low vowels
- Substantively Biased Feature-Based Learning: Abstract learning, constrained by universal grammatical tendencies
  - generalization to mid and low vowels

Predictions: Experiment 1

Hypothesis	Mid Vowel	Low Vowel
Segment	X	X
Formally-Restrictive	√	X
General	√	√
Substantively - Biased	√	√

Participants (all experiments)

- Adult native English speakers
- Johns Hopkins Undergraduate Students (for extra credit)
- 12 participants in each training condition

Experiment 1: Training

- 4 Vowels in training: 2 Hold-Out Conditions
    - Low Hold-Out: [i, e, u, o]
    - Mid Hold-Out: [i, u, æ, a]
- 24 items, each played 5 times
    - Stem followed by Stem + Suffix
    - bige, bigemi budo, budomu
- Controls
    - 48 stems, 24 harmonic stems, 24 disharmonic stems

Experiment 1: Test

- Forced choice
  - Heard 2 suffixed forms
  - Pick Form 'Most likely to be in language'
    - » bidimi bidimu
- 36 test items
- 3 test conditions:
  - Old Items (Identical to training)
  - New Items (Identical segments)
  - New Vowels (mid vowels/low vowels)

The Role of Generalization

- High Performance on Old Items:
  - form-by-form learning
- High Performance on New Items:
  - abstract rule
- High Performance on New Vowels:
  - feature-based rule

Experiment 1: Results

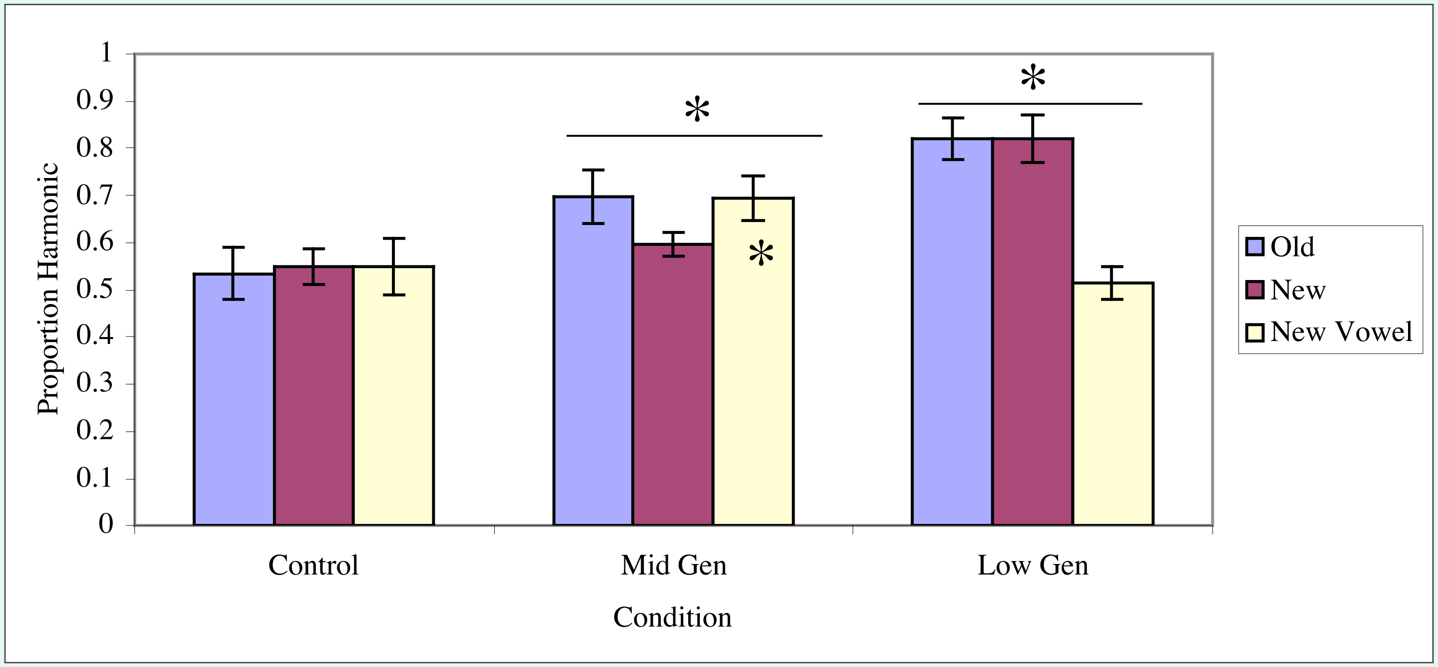


Figure 1: Proportion of Harmonic Responses for All Conditions

- Controls at chance
- Mid Hold-Out generalized to Mid vowels, but did numerically worse on new items (low vowels)
- Low Hold-Out generalized to new items, but not low vowels

Exp 1 Results Summary

- Generalization to Mid Vowels
  - Supports Feature-Based Accounts
- No Generalization to Low Vowels
- Round Confound
  - suffix [mi]/[mu] alternates in backness AND rounding
  - Low vowels unround
    - may have lead to poor generalization
    - Low Vowels do not participate in round harmony
      - supports substantive-biased hypothesis

Predictions: Experiment 1

Hypothesis	Mid Vowel	Low Vowel	Overall
Segment	☹	√	☹
Formally-Restrictive	√	√	√
General	√	☹	☹
Substantively - Biased	√	√	√

Experiment 2

- Are differences in generalization in Experiment 1 based on cross-linguistic tendencies or general dispreference for low vowels?
- Goals of Exp 2
  - Make front/back distinction unambiguous
  - Test Generalization for mid vs. high vowels
  - Test Perception of low vowels

Experiment 2: Low Vowel Suffix

- Front vowels trigger: [-mæk]
- Back Vowels Trigger: [-mak]
- Hold-Out Conditions:
  - Hold Out Mid Vowels
    - [i, æ], [u, a]
  - High Hold-Out
    - [e, æ], [o, a]

Exp 2: Substantively Biased

- If generalization based on typological frequencies
  - Generalization to Mid Vowels
  - Less robust generalization to High Vowels
    - particularly less generalization to High Front Vowels
      - Cross-linguistic tendency for non-participation of high front vowels (e.g., Finnish)

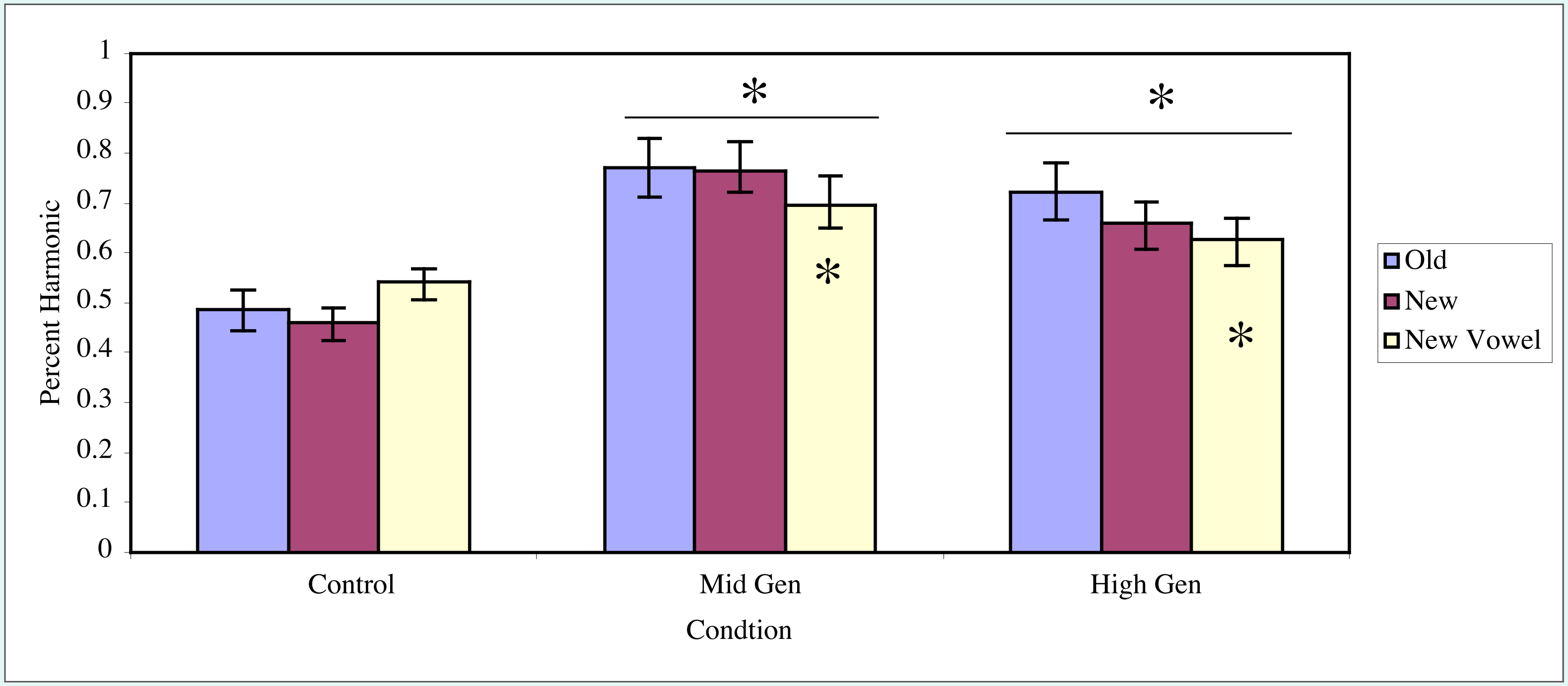
Predictions: Experiment 2

Hypothesis	Mid Vowel	High Vowel
Segment	X	X
Formally-Restrictive	√	X
General	√	√
Substantively - Biased	√	√ /X

Experiment 2: Perception Task

- To test whether participants perceive the difference between front/back pairs, especially in the low vowels
- AXB paradigm
    - Participants asked to judge whether X is the same as A or B
        - teteto X =A
        - tetoto X = B
    - If difference is perceived, then performance should be very high, if no difference is perceived, performance should be low.
- Used as screening (all participants under 70% correct dropped; this occurred for less than 10% participants)

Experiment 2: Results



- Generalization in Both Training Conditions
  - more robust in Mid Hold-Out

Experiment 2: Results

- Generalization more robust to mid vowels than high vowels
  - greater generalization to back high vowels
    - 57% high front harmonic
    - 68% high back harmonic
  - Cross-linguistic tendency for non-participation of high front vowels (e.g., Finnish)
- Perception results at ceiling

Predictions: Experiments 1& 2

Hypothesis	Exp 1	Mid Vowel	High Vowel	Overall
Segment	☹	☹	☹	☹
Formally-Restrictive	√	√	☹	☹
General	☹	√	√	☹
Substantively- Biased	√	√	√	√

Experiment 3: Height Harmony

- When do learners postulate parasitic (restrictive) harmony rules?
  - Further distinguish between different feature-based approaches

- Substantively-Biased Hypothesis:
  - Parallels with Cross-linguistic Typologies
- Formally-Restrictive Hypothesis
  - Always form restricted, parasitic-type rule
- General Feature-Based Learning Hypothesis
  - Never form restrictive, parasitic rule

Experiment 3: Height Harmony

- Height Harmony
  - Parasitic on Tenseness
  - But not Backness
- Substantively Biased Hypothesis
  - Learners exposed to tense vowels undergoing vowel harmony will form parasitic rule
    - not generalize to lax vowels
  - Learners exposed to front vowels undergoing height harmony will form general rule
    - generalize to back vowels

Predictions: Experiment 3

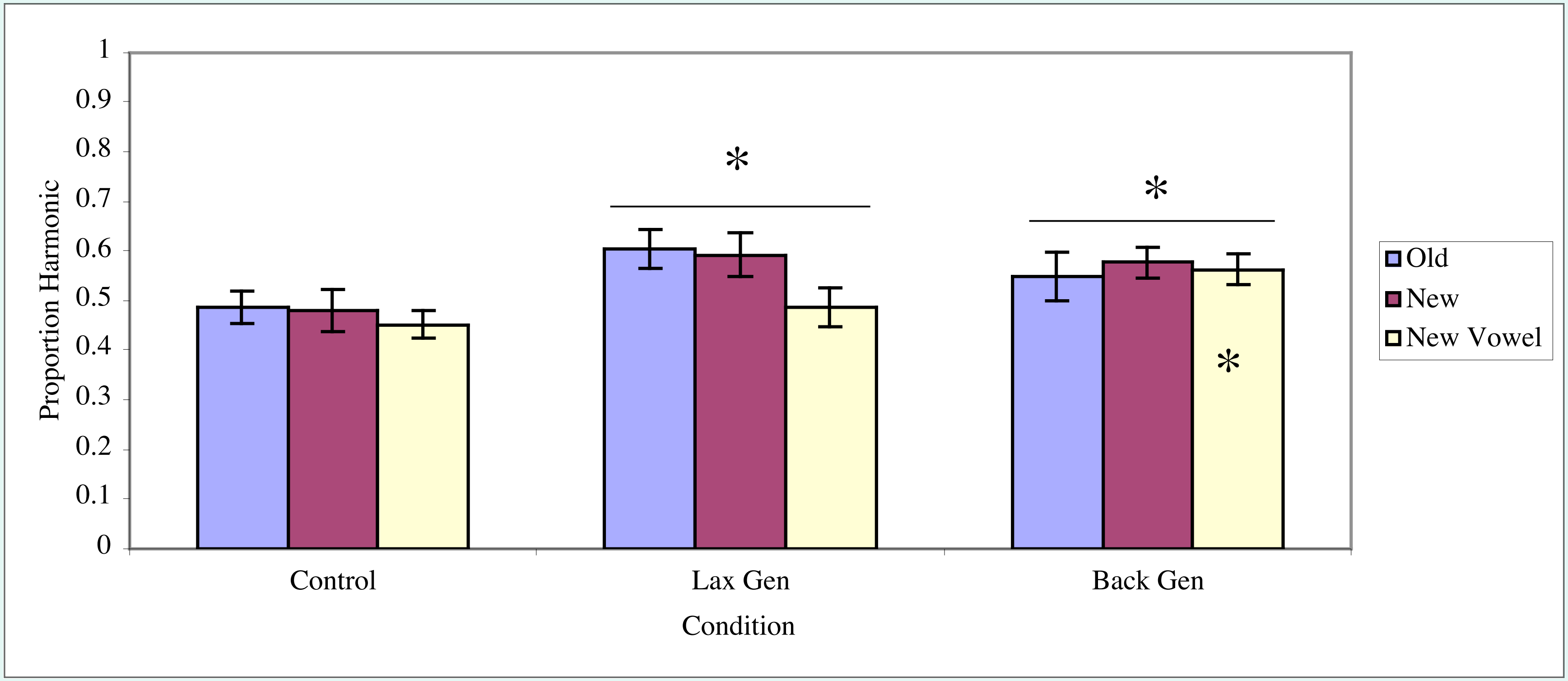
Hypothesis	Lax Vowel	Back Vowel
Segment	X	X
Formally-Restrictive	X	X
General	√	√
Substantively - Biased	X	√

Experiment 3: Materials

- Suffix: [-mi], [-me]
- Three training conditions:
  - Control
  - Lax Hold-Out [i, u, e, o]
  - Back Hold-Out: [i, ɪ, e, ɛ]

[+HIGH]	i ɪ	u
[–HIGH]	e ɛ	o

Experiment 3: Results



- Learning in both Conditions
- Generalization to Back Vowels
- No Generalization to Lax Vowels

Predictions: Experiments 1- 3

Hypothesis	Exp 1	Exp 2	Lax Vowel	Back Vowel	Overall
Segment	☹	☹	√	☹	☹
Formally-Restrictive	√	☹	√	☹	☹
General	☹	√	☹	√	☹
Subst-Biased	√	√	√	√	√

The Substantively-Biased Learner

- Generalization to Back but not Lax vowels Supports the Substantively-Biased Learning Hypothesis
- Substantively-Biased Learning:
  - abstract, feature-based representations
  - rules posited in line with typological frequencies

Experiment 4 Novel Suffixes

- Feature-based Generalization to novel vowels
  - How abstract is the rule formed?
  - Just memorized association to suffix?
- Can learners generalize to novel suffixes?
  - Evidence for more abstract rule

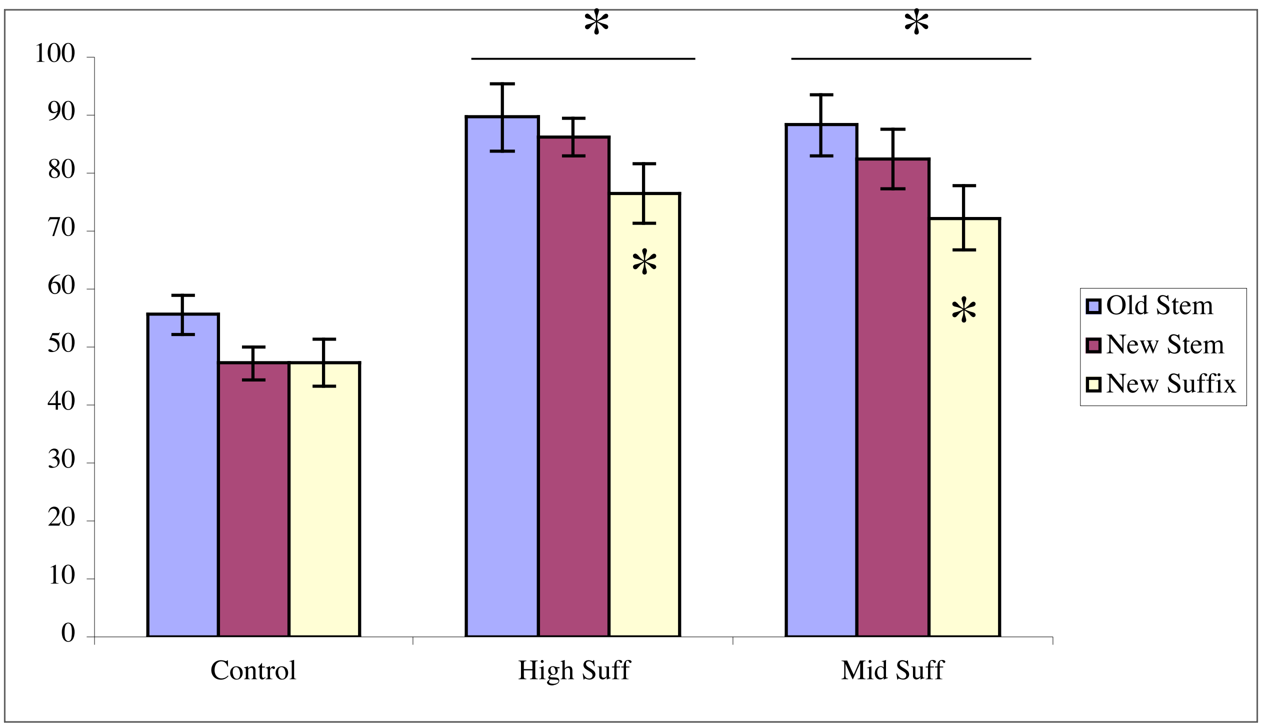
Experiment 4-Novel Suffixes

- Round Harmony Rule
- 4 vowel inventory [i, u, e, o] (all conditions)
- 3 conditions
  - Control
  - Generalize to Mid-Vowel Suffixes
    - train on high-vowel suffix
  - Generalize to High-Vowel Suffixes
    - train on mid vowel suffix
- CVCV stems
- High suffix
    - either [-mi]/[-mu], [-gi]/[-gu]
- Mid Suffix
    - Either [-me]/[-mo], [-ge]/[-go]

Experiment 4: Test

- 3 Conditions, 36 items
- Old
    - Stem and suffix exactly same as training
- New Stem
    - suffix identical to training
    - Novel Stem
- New Suffix
    - Stem identical to training
    - Novel suffix vowel
    - Different Consonant
        - if training suffix [-mi]/[-mu], novel suffix [-ge]/[-go]

Exp 4: Results



- All Groups Learned
- Generalization to Novel Suffixes

Exp 4: Summary

- Generalization to novel suffix vowel
- Both for Mid and High Vowels
- Supports feature-based learning
- Rule more abstract than memorized stem + Suffix association

Substantively-Biased Learning

- Abstract, feature-based representations
- Generalize to multiple alternations
- Rules posited in line with cross-linguistic typology

Alternative, Phonetic Interpretations

- Exemplar Learning: Match statistical co-occurrence of segments to exemplars heard in training
  - Exemplar-based version of the segment-based hypothesis
  - Learning outside training space (Marcus 1999) goes against it
- Acoustic Distance to Suffix: If new segments are too far from the suffix, won't generalize
  - Exp. 3- Lax vowels closest to suffix vowels [i]/[e], but no generalization
- Acoustic Distance of Novel Segments: If novel segments are too close acoustically, won't be able to match to suffix
  - Exp. 2: predicts best generalization to high vowels [i]/[u] since are furthest apart, but generalization here was less robust

Conclusions

- Abstract features used in learning
- Universal grammatical principles constrain learning
  - What are they, exactly?
- Artificial grammar experiments can be used to test phonological theories
  - More research, more refined paradigms, needed

THANK YOU!

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